

## **Exploring Biodiversity: Past, Present, and Future**

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**The field of biodiversity studies now embraces the activities of many disciplines, including paleobiology, systematics, ecology, and conservation biology. The breadth of the basic scientific research in this field is well represented by the collection of papers in this special issue. These studies present new data, syntheses, and opinions on how we can best document and preserve biodiversity given the limitations of human behavior and resources. All the contained studies emphasize the importance of interdisciplinary collaboration, integration of data from diverse sources, and collective scientific and social action.**

Since the neologism ‘biodiversity’ was coined by E.O. Wilson in 1986 as a catchy replacement for ‘biological diversity’, the word has achieved broad currency in the professional and popular scientific and environmental literature. In the last twenty years, worries over the hastening pace of extinctions, the ramifications of global warming, and the ecological and economic impacts of invasive species have spawned unprecedented levels of awareness and concern for the Earth’s biota. What began as a single word — biodiversity — is now an entire field of study, which brings together paleobiologists, systematists, ecologists, climatologists, biogeographers, geneticists, and conservation biologists, just to name a few. The idea of having the California Academy of Sciences host a symposium with a focus on the dynamic and multidisciplinary theme of “Biodiversity: Past, Present, and Future” emerged early in the course of planning for the 150<sup>th</sup> anniversary of the Academy, which was celebrated throughout 2003. Thanks to the generosity of the Pacific Division of the American Association for the Advancement of Sciences, the two-day symposium was co-hosted by the Division and the Academy, and held on the campus of San Francisco State University on June 16–17, 2003 as part of the Pacific Division’s annual meeting. The symposium was well attended and enthusiastically received. Those who were able to attend most or all of the papers were amply rewarded with papers ranging from the data-rich and synthetic to the innovative and provocative. Some exceptional papers triumphed in all of these areas.

The papers in this volume represent a good sample of the basic research underpinning the emerging field of biodiversity sciences today, and celebrate the breadth of inquiry now being explored by scientists at the California Academy of Sciences and many other institutions. Whereas many conferences and volumes dedicated to biodiversity have focused exclusively on living biotas, this collection comprises papers exploring biodiversity in the past, present, and future, and provides the reader with vivid insights as to how these studies can mutually inform one another.

The questions broached in these papers are dauntingly big. How do we ascertain and measure biodiversity? How has biodiversity changed through time? To what extent is loss of biodiversity being hastened by recent human activities? How can we realistically approach the societal issues raised by biodiversity and conservation studies without losing direction and heart? The first four

papers in this collection represent dramatically different types of investigations of past biodiversity. Geerat Vermeij breaks new ground by probing the origins of the fundamental patterns of species diversity. He specifically examines the roles played by global temperature in creating the gradients of species diversity that we observe in today, and by competition for local limiting resources in promoting functional differentiation and specialization of species. Douglas Erwin seeks new answers to questions surrounding the origins of the Cambrian metazoan radiation by integrating data from paleoecology and developmental biology. William DiMichele, Robert Gastaldo and Hermann Pfefferkorn provide innovative insights into the rules governing the assembly of ecological communities through detailed examination of Paleozoic tropical ecosystems. Their focus on the role of vascular plants in creating new niches for other organisms in early terrestrial ecosystems is particularly enlightening. Patterns of species diversity and species association through time are also the subject of the paper by Anthony Barnosky and Alan Shabel. These authors explore these phenomena through an examination of mammalian species diversity from a single site in North America in both Pleistocene and historic times, and conclude that patterns of species association and community structure are remarkably robust, even in the face of major environmental changes.

Five papers in this collection focus on biodiversity of modern biotas. The first of these, by Daniel Dykuizen, will startle most biologists dealing with multicellular organisms by bringing forth a definition of bacterial species based on DNA hybridization that relegates metazoan species to the role of genetically depauperate bystanders in evolution. Based on his conservative definition of bacterial species, Dykuizen estimates that the Earth is home to at least one billion species of bacteria. Questions surrounding the actual numbers of metazoan species in terrestrial ecosystems and the factors influencing species diversity are explored for two families of beetles by Terry Erwin, María Pimentia, Oscar Murillo, and Valeria Aschero. The results of their study challenge widely held assumptions concerning the composition of assemblages of herbivore and predator species in tropical ecosystems, and provoke re-examination of the methods we use to ascertain and preserve species in such ecosystems. Insect biodiversity and its ascertainment are also the subjects of the paper by Brian Fisher, in which he describes his ambitious and large-scale project for inventorying and reporting the ant fauna of Madagascar. He convincingly demonstrates that it is possible to undertake and broadcast a comprehensive inventory of a speciose biota, but that the costs in terms of money and human effort are significant. This contribution and that by T. Erwin and colleagues provide rare insights into the real costs and benefits of biodiversity analyses, and should provide important basic data for conservation strategists and policy planners. The issues involved with the conduct of multi-taxon surveys in the populous and biodiverse country of Vietnam are broached by Eleanor Sterling and Martha Hurley. Their study highlights the challenges faced by biodiversity scientists working in threatened habitats, and reinforces the oft-forgotten points that wide-scale surveys can yield discoveries of new metazoan species and range extensions of familiar species in even fairly well-studied terrestrial habitats. Their exemplary study also emphasizes the importance of teams employing comparable methodologies conducting biological inventories in countries or regions that span a wide range of latitudes or ecological zones. Julia Berger, in her paper reviewing the work of the All Species Foundation (ALL), illustrates how the goals of organizations like the ALL must adapt to the changing intellectual and financial environments in which they operate. The original goal of the ALL — the ascertainment of all remaining species on Earth in 25 years — was scaled down in 2002 to the more modest, but more realistic and important, goal of developing tools and technologies to facilitate the creation and dissemination of taxonomic information.

The final three papers in this collection provide varied and provocative food for thought on the status and prospects of biodiversity. Michael McKinney begins this trilogy by examining the

impact of humans on patterns of biodiversity. His troubling but accurate description of a 'New Pangea' emphasizes the human penchant for dispersing species, creating new and unlikely mixtures of species, and fragmenting habitats. His is not the usual treatment of invasive species at a local level, but a clarion call to scientists and policy makers to examine the costs of human behavior at a global scale. In the following paper, Paul Ehrlich challenges systematic biologists to face the problems of biodiversity decline by coming up with more efficient methods for sampling the world's biota and promulgating the results of their investigations. Far from advocating ascertainment of all species, he supports the development of selective inventories, especially of metazoan biotas that are already reasonably well known, and the concerted cooperation of systematists and ecologists in disseminating relevant information on biodiversity to the scientific community and makers of public policy. The last paper in this volume, by Peter Raven, calls attention to the problems of human impacts on the Earth's biota from a different perspective. Humans are a destructive and manipulative species, but they also vary greatly from one region and economic sphere to the other in their tendencies. They are also the only species to be fully aware of the local and global impacts of their activities. Raven stresses that awareness at this point is far from sufficient, however, and that we must apply our faculties and considerable creativity to reining in our species' ecologically malignant tendencies for overconsumption.

Four important and overarching messages emerged from the symposium and from the papers in this collection. The first is that an understanding of biodiversity at the local, regional, or global levels is possible only if individual scientists are more explicitly integrative and interdisciplinary in their work. This may involve investigation of literature in cognate fields, or actual discussion and collaboration with scientists in these fields. Systematics and ecology - the very foundations of biodiversity studies - must put aside their minor doctrinal differences and rise to the challenges now facing their science and their planet. The second is that scientists engaged in research in any one of the disciplines supporting biodiversity science must make an effort to see that the results of their work are disseminated beyond the typically very small academic circles in which most of navigate. This is especially true of scientists who carry out surveys or studies with implications at any level for public policy. The third is that we must get a lot better at advertising the importance and relevance of what we do to the general public. The discovery of biodiversity should, it has been argued, garner as much public attention and financial support as space exploration because it is just as exciting. This is demonstrably not the case, however. Individual scientists really can make a difference here, by reaching out in whatever ways they can to communicate the marvels of life of Earth to others. The fourth and final message is that those of us who engage in the scientific study of biodiversity are also citizens of the Earth. Our social responsibilities should be informed by our research, and activism at some level should become as much a part of our lives as fieldwork and the writing of papers.

Taken together, the papers in this collection inspire awe — at the vast amounts we know and don't know — and, most importantly, action.